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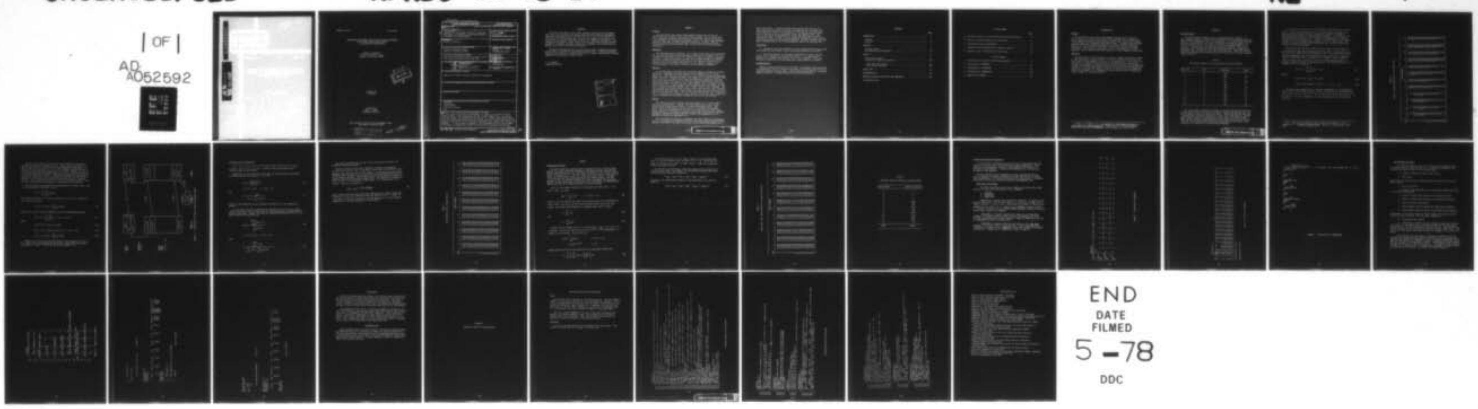

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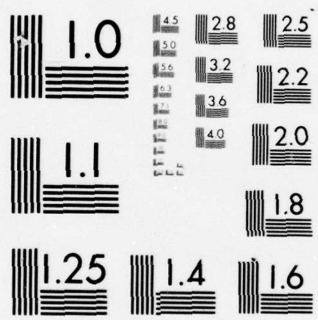

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FORECASTING THE NUMBERS AND TYPES OF ENLISTED PERSONNEL IN THE UNITED STATES MARINE CORPS: AN INTERACTIVE COHORT MODEL

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This report describes the development of a model to forecast the total enlisted Marine Corps strength at the end of each quarter for 1 or 2 years into the future. The method involves the use of a simple cohort model, which has been implemented interactively and allows users to forecast the effects of changes in the recruit 2-3-4 year mix, education level, racial mix, or any combination. It also allows for gaming of the continuation rates, and provides long-range or steady-state results of particular recruitment policies.

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FOREWORD

The effort described in this report supports the Enlisted Force Management Tools work unit under the Marine Corps Personnel Resources Management exploratory development task area (ZF55-521-101). The overall objective of this task area is to provide tools to assist the manager in moving the personnel flows in desired directions within strict budgetary constraints. The managerial environment in which these tools are used requires quick response methods to facilitate optional acquisition, assignment, and distribution of Marine Corps officer and enlisted personnel.

The model described herein is currently being used for manpower forecasting purposes at Code MPI-20, Headquarters Marine Corps. Special acknowledgements are due to MAJ M. J. Hester and CAPT W. W. Sevon of Code MPI-20 for their background consultations on this project.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

The uncertainty under which large manpower systems such as the U.S. Marine Corps are forced to work creates many problems, such as budget overruns, suppressed promotion opportunities, insufficient quality and quantity of recruitment, and inadequate reenlistment rates. To combat these problems, modeling techniques are being developed to determine feasible promotion policies and flow structures which meet certain force structure and budget constraints.

Objective

The objectives were to develop: (1) a simple cohort model for forecasting the total enlisted Marine Corps strength at the end of each quarter for 1 or 2 years into the future, and (2) an interactive computer program to implement the model. Using this program, the user can introduce changes in retention policies and recruit population and observe the resulting projected future enlisted force end strengths immediately on his computer terminal, thus allowing gaming of the various retention and recruitment parameters.

Approach

It has been shown previously that retention behavior patterns of enlisted marines are reasonably consistent within certain subgroups of the total population. The important characteristics to be used in forming the subgroups appear to be race, educational level, and length of first-term enlistment (FTE) of new recruits. A simple cohort model was developed, placing all recruits and current marines into one of 12 cohorts uniquely determined by their race, educational level, and length of FTE. Since marines with a length of service (LOS) greater than 5 years showed retention behavior that was roughly the same for all cohorts, they were grouped into a single "career force" category. All other marines were characterized by their cohort type and their LOS. Forecasting equations were developed from the model, and the retention parameters were derived from historical data. The forecasting equations were then incorporated into an interactive APL program in such a way as to allow the user to game the various retention and recruitment parameters directly at his terminal.

Results

The model can be used for short-term forecasting (1 or 2 years) under a given recruitment policy. Further, the basic model can be used to show long-range or steady-state effects of a fixed recruitment policy. This can be useful in determining certain trends of a particular recruitment policy, such as the steady-state fraction of marines with less than a high school education. The model is currently being used by the staff of Manpower Management Information Systems (MPI-20), Marine Corps Headquarters as a personnel planning and management tool.

The interactive APL program to implement the model, which was implemented in close cooperation with the MPI-20 staff, uses three APL functions to input, display, and correct the stocks of marines in each cohort/LOS category for a

given time period. A fourth function interactively asks the user for data concerning the period over which the projection is to be done, the total number of recruits in each quarter of this period, and the breakdown of recruits by race, educational level, and length of FTE. The user is then given the opportunity to change the historically derived continuation rates. A report is then generated showing the recruit policy used and the quarterly end strengths obtained. The user can then rerun the model, changing some or all of the parameters used in the previous run.

Conclusions

1. Historical data are available to obtain continuation rate values for each cohort/LOS type needed in the forecasting equations of the model.

2. Retention behavior is relatively independent of cohort type for marines with a length of service greater than 5 years, allowing such marines to be grouped into a single "career force" category. This substantially reduces the data and computation requirements of the model.

Recommendations

Based on gaming experience with the model, optimization features should be implemented in order to evaluate strategies for attaining both short- and long-term manpower planning goals. These should include features to measure budgetary effects of various promotion and retention policies.

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INTRODUCTION

Problem

The uncertainty under which large manpower systems such as the U.S. Marine Corps are forced to work creates many problems, such as budget overruns, suppressed promotion opportunities, insufficient quality and quantity of recruitment, and inadequate reenlistment rates. To combat these problems, modeling techniques are being developed to determine feasible promotion policies and flow structures that meet certain force structure and budget objectives. The purpose of such models is to aid the manager in moving personnel flows in desired directions subject to strict budgetary constraints.

Objective

The objective of this effort was to develop a simple cohort model, similar to that described by Zacks and Haber,[1] for use in forecasting the total enlisted Marine Corps strength at the end of each quarter for 1 or 2 years into the future. To implement the model for use in Marine Corps enlisted end strength forecasting, a secondary objective was to develop an APL program with a number of features that allows the user to interact in the forecasting procedure by (1) introducing changes in the mix of recruits by race, education, length of enlistment, or a combination of these factors, and (2) gaming projected changes in retention policies.

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[1]Zacks, S., & Haber, S. E. A procedure for forecasting the size of a force subject to random withdrawal. Washington, DC: George Washington University, Institute of Management Science (Report No. T-312), 1975.

APPROACH

The Basic Model

It has been shown previously (e.g., by Zacks and Haber, Footnote 1) that retention behavior patterns of enlisted marines are reasonably consistent within certain subgroups of the total population. It has been found that the important characteristics to be used in forming the subgroups appear to be race, educational level, and length of first-term enlistment (FTE) of new recruits. In this study, race was represented by Caucasians (C) and non-Caucasians (NC); education by high school graduates (HS) and nonhigh school graduates (LHS); and FTE, by 2, 3, and 4 year enlistees. Thus, all recruits and current marines can be uniquely placed into one of the 12 cohorts (groups) shown in Table 1.

Table 1

The Twelve Cohorts of the Enlisted Marine Corps Personnel

Cohort No.	FTE	Education	Race
1	2	LHS	C
2	2	LHS	NC
3	2	HS	C
4	2	HS	NC
5	3	LHS	C
6	3	LHS	NC
7	3	HS	C
8	3	HS	NC
9	4	LHS	C
10	4	LHS	NC
11	4	HS	C
12	4	HS	NC

The cohort model classifies the number of enlisted marines available during any given quarter not only by the cohort to which they belong, but also by the length of time each marine has served. Historical data are then used to estimate the fraction of marines in a given cohort and length of service (LOS) category who will continue their service into the next time period. These values, together with information on the number and cohort mix of new recruits, can be used to make short-term projections of force size. This procedure is illustrated in the following paragraphs.

Let $S_i(t;u)$ be the "stock" of enlisted Marine Corps personnel in cohort type i at time t with LOS equal to u.[2] The time periods are taken to be quarters, and the phrase "at time t" means the last day of quarter t. For consistency, the LOS is also measured in quarters. If a person enters the Marine Corps in quarter t and is counted as being present at time t, then we say he has LOS equal to 1. Thus, if he enters in t and is counted at time $t + k$, $k \geq 0$, then he has LOS equal to $k + 1$. Table 2 gives the stocks at the end of March 1976 of marines who were listed as being still in their first-term enlistment.

Let $q_i(u)$ be the fraction of those in cohort type i with LOS equal to u at some time t who will continue in service to time $t + 1$ with LOS $u + 1$. The $q_i(u)$ are commonly called "continuation rates." By using this notation, we are assuming that they are independent of the actual time t. This assumption is modified later. Let $g_i(t)$ be the number of new recruits who enter in cohort type i in period t, and let m be the maximum number of periods a person can spend in the Marine Corps. The total stock $S(t + 1)$ of marines at $(t + 1)$ is given by

$$S(t + 1) = \sum_{i=1}^{12} \sum_{u=1}^{m} S_i(t + 1;u) \quad , \tag{1}$$

where

$$S_i(t + 1;1) = g_i(t + 1)\, q_i(0) \tag{1.1}$$

$$S_i(t + 1;u) = S_i(t;u-1)\, q_i(u-1) \quad , \; u = 2,3,\ldots,m. \tag{1.2}$$

In order to use equation (1) to forecast end strength, it is necessary to know (1) the cohort stocks $\{S_i(t;u)\}$ for all i and all u, (2) the continuation rates $\{q_i(u)\}$ for all i and all u, and (3) the future recruit inputs $\{g_i(t + 1)\}$ for all i. It is the determination of these three sets of data to which we now turn.

---

[2]For a detailed description of cohort models, see Grinold, R. C., & Marshall, K. T. <u>Manpower planning models</u>. New York: North-Holland Press, 1977.

Table 2

Stocks of Enlisted Marines on 31 March 1976

	Cohort Number											
LOS	1	2	3	4	5	6	7	8	9	10	11	12
1	3	0	3	2	1706	301	1424	422	2419	410	2982	588
2	5	4	14	2	931	134	1256	299	2635	497	3418	797
3	48	12	221	33	907	132	1683	387	2441	462	5563	1166
4	165	29	879	117	495	81	1041	236	1749	336	4276	907
5	527	92	806	137	928	211	645	147	3143	897	2563	582
6	543	154	804	202	672	210	495	187	2372	793	2013	503
7	845	235	1926	541	736	247	936	299	2180	697	3841	816
8	380	128	899	387	301	108	560	196	1107	356	2685	700
9	197	80	248	85	794	200	545	143	1981	583	1433	340
10	83	39	140	51	547	124	436	108	1487	435	1179	334
11	43	27	174	34	508	122	876	185	1688	387	2846	624
12	23	31	50	21	414	96	460	124	1721	400	1892	407
13	26	13	52	22	126	39	123	50	1502	394	1147	350
14	20	12	25	11	61	18	70	28	1187	360	1176	404
15	30	19	74	24	52	24	123	41	1282	354	2409	530
16	31	20	24	18	40	11	62	28	932	206	1562	281
17	22	7	17	9	26	6	25	11	325	70	285	86
18	14	4	7	3	19	8	14	4	150	17	186	44
19	6	5	14	5	11	0	33	10	119	17	279	61
20	4	1	6	4	10	2	19	3	101	32	157	28

The new recruit input in future years will be given to the model by the user and thus we can dispose of (3). Table 2 shows the stocks of marines who are still in their first-term enlistment at some given t for each cohort i, but only for u = 1,2,...,20. Marines can reenlist and remain in service 30 years; thus, m is 4 x 30 = 120. However, as the LOS of a marine increases beyond his FTE period, there is little distinction to be found among the 12 cohorts. These marines essentially form what is called the "career" force, and continuation in service of these people is governed by a different set of factors than those affecting first-term marines. Thus, we modify equation (1) in the following way to reduce both the size of the model and the number of parameters to be estimated.

Let c(t) be the total number of enlisted marines in service time t with 21 or more quarters of service. Thus,

$$c(t) = \sum_{i=1}^{12} \sum_{u=21}^{m} S_i(t;u).$$

Now assume that $q_i(u) = q$ for all $u \geq 20$ and $i = 1,2,\ldots,12$. Using (1.2) it is easy to show that

$$c(t+1) = [c(t) + \sum_{i=1}^{12} S_i(t;20)]q. \tag{2}$$

Equation (1) and (2) are now combined to give the forecasting equation

$$S(t+1) = \sum_{i=1}^{12} \sum_{u=1}^{20} S_i(t+1;u) + c(t+1) \tag{3}$$

where

$$S_i(t+1;1) = g_i(t+1)\, q_i(0) \tag{3.1}$$

$$S_i(t+1;u) = S_i(t;u-1)\, q_i(u-1),\ u = 2,3,\ldots,20 \tag{3.2}$$

$$c(t+1) = [c(t) + \sum_{i=1}^{12} S_i(t;20)]q. \tag{3.3}$$

Equation (3) requires only 241 continuation rates compared to 1452 in (1). This gives a considerable saving in data, computation, and storage requirements. Figure 1 illustrates the flows assumed in (3).

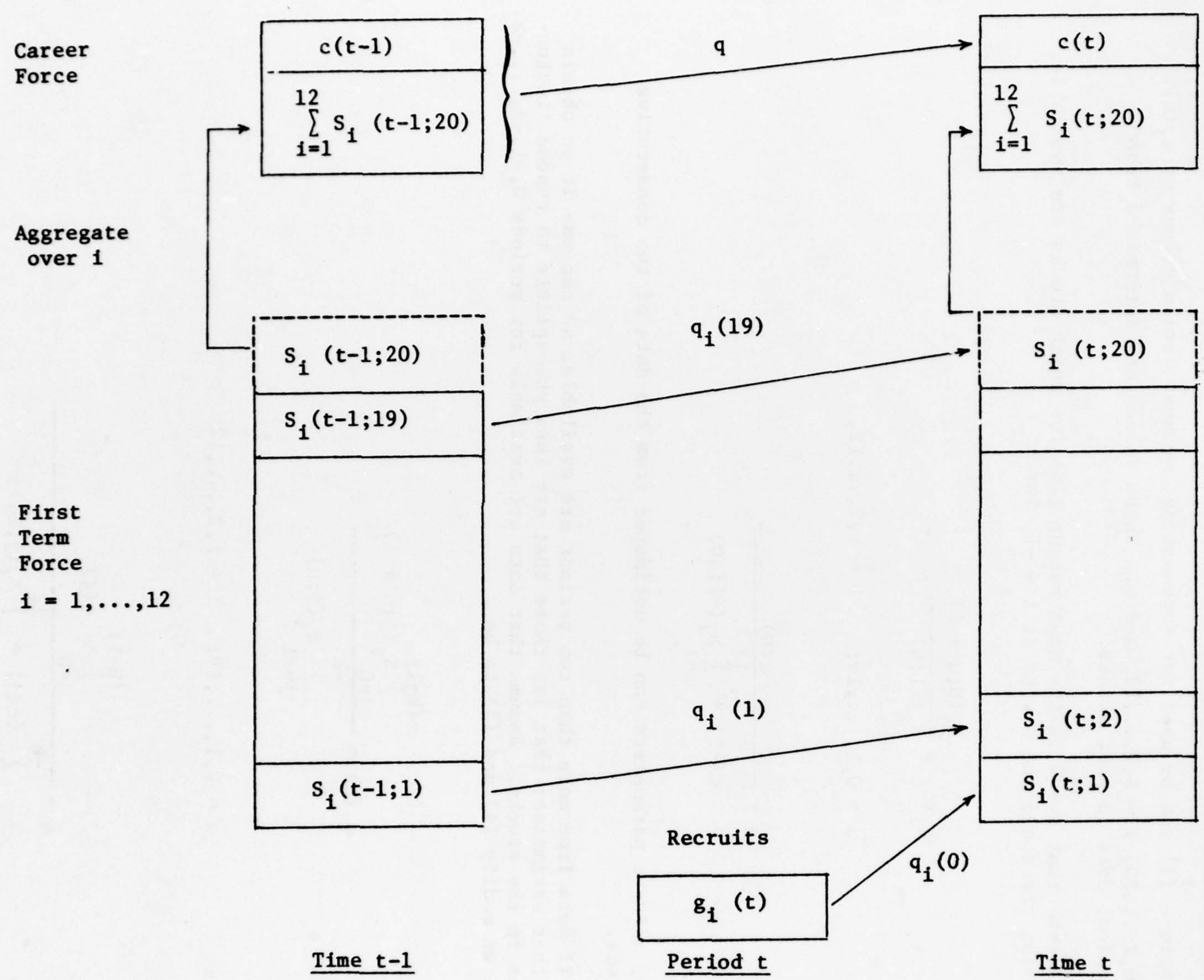

Figure 1. Illustration of flows in the forecasting model.

Continuation Rate Estimation

Before (3) can be used for forecasting, we must obtain values of $q_i(u)$, $u = 0,1...,19$, $i = 1,2...,12$, and q. These values are determined from historical data on past stocks.

Assume that $t = 0$ is the most recent time for which stocks are available. By using these and the stocks at $t = -1$, let

$$q_i(u) = \frac{S_i(0;u+1)}{S_i(-1;u)}, \tag{4}$$

$$u = 0,1,...,19; \quad i = 1,2,...12,$$

and

$$q = \frac{c(0)}{c(-1) + \sum_{i=1}^{12} S_i(-1;20)}. \tag{5}$$

Thus, all the parameters can be estimated from the data of two consecutive periods.

If data from more than two periods are available, we can use it to obtain smoother estimates; that is, those that are less susceptible to random fluctuations in the stocks. Assume that data are available for periods $0,-1,-2,...,-k$. Then we modify (4) and (5) to be

$$q_i(u) = \frac{\sum_{j=0}^{-(k-1)} S_i(j;u+1)}{\sum_{j=-1}^{-k} S_i(j;u)} \tag{6}$$

$$u = 0,1,...,19; \quad i = 1,2,...,12$$

and

$$q = \frac{\sum_{j=0}^{-(k-1)} c(j)}{\sum_{j=-1}^{-k} \{c(j) + \sum_{i=1}^{12} S_i(j;20)\}}. \tag{7}$$

The values obtained using (6) and (7) for any given k are said to be determined using rate method k.

Recruit attrition in the first 6 months of service is measured by $(1-q_i(0))$ and $(1-q_i(1))$, and is considered controllable by the Marine Corps. Estimates from past data have little meaning. In the interactive APL model described later in detail, recruit attrition is entered directly by the user at the computer terminal. The 6-month attrition of LHS and HS recruits is normally about 20 and 10 percent respectively. The conversion of these into $q_i(0)$ and $q_i(1)$ is illustrated for some cohort i if a 6-month rate r is entered. They are calculated by

$$q_i(0) = q_i(1) = \sqrt{1 - (r/100)}, \tag{8}$$

which spreads attrition evenly over the 6-month period. Table 3 gives the continuation rates $q_i(u)$ obtained using rate method 2 with t = 0 equal to 3-31-1976, and recruit attrition for LHS and HS equal to 15 and 12 percent, respectively. The value obtained for q was 0.980.

Table 3

Continuation Rates Using Method 2

	Cohort Number											
LOS	1	2	3	4	5	6	7	8	9	10	11	12
0	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
1	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
2	1.251	1.583	0.997	1.070	1.011	1.098	0.986	1.038	0.995	1.032	0.983	1.012
3	0.948	1.032	0.996	0.985	0.973	0.990	0.976	0.985	0.956	0.984	0.986	0.991
4	0.943	0.945	0.996	1.003	0.932	0.915	0.977	0.955	0.927	0.938	0.979	0.965
5	0.927	0.906	0.992	0.977	0.913	0.893	0.994	0.962	0.925	0.908	0.985	0.996
6	0.952	0.946	0.984	0.968	0.914	0.940	0.986	0.951	0.932	0.886	0.981	0.967
7	0.841	0.815	0.912	0.912	0.936	0.855	0.971	0.963	0.926	0.916	0.981	0.971
8	0.260	0.321	0.354	0.356	0.914	0.865	0.981	0.992	0.911	0.883	0.988	0.978
9	0.563	0.516	0.715	0.610	0.906	0.908	0.963	0.978	0.909	0.921	0.968	0.948
10	0.464	0.652	0.800	0.634	0.930	0.883	0.954	0.957	0.903	0.855	0.976	0.942
11	0.626	0.937	0.783	0.821	0.867	0.860	0.875	0.873	0.900	0.886	0.979	0.955
12	0.674	0.639	0.494	0.667	0.250	0.312	0.253	0.342	0.918	0.875	0.985	0.956
13	0.712	0.649	0.876	0.846	0.517	0.576	0.626	0.687	0.926	0.909	0.971	0.970
14	0.892	0.703	0.840	0.758	0.636	0.697	0.786	0.763	0.935	0.918	0.971	0.940
15	0.800	0.775	0.810	0.805	0.745	0.611	0.835	0.800	0.877	0.869	0.906	0.930
16	0.923	0.722	0.659	0.714	0.763	0.714	0.867	0.727	0.286	0.323	0.283	0.464
17	0.667	0.643	0.875	0.438	0.914	0.909	1.000	0.824	0.607	0.621	0.645	0.742
18	0.700	1.000	0.885	0.889	0.929	0.600	1.000	1.000	0.762	0.762	0.815	0.773
19	0.600	0.833	0.688	0.909	0.914	1.000	1.032	0.733	0.840	0.927	0.917	0.908

RESULTS

Steady-State Results

The model summarized mathematically in equation (3) is currently being used by the staff of Manpower Management Information Systems (Code MPI-20), Marine Corps Headquarters, for short-term forecasting (1 or 2 years) under a given recruitment policy. The basic model can also be used to show the long-range, or steady-state, effects of a fixed recruitment policy. Although it is unlikely that the system parameters will remain constant over many periods or that recruitment policies will remain unchanged, the long-range behavior of the system under a given policy is often useful in showing trends. These trends can act as warning signals of future problems.

Let L_i be the random lifetime of an individual of cohort type i. Let $Q_i(\ell) = P[L_i > \ell]$; then

$$Q_i(\ell) = \prod_{u=0}^{\ell} q_i(u) \quad , \quad \ell = 0,1,2,\ldots, m. \tag{9}$$

Now let λ_i be the average time spent in the Marine Corps of an individual in cohort type i, and let g_i be the fixed quarterly recruit input into this cohort. The stocks S(t) converge to a constant stock level S, where

$$S = \sum_{i=1}^{12} \lambda_i g_i \tag{10}$$

and

$$\lambda_i = \sum_{\ell=0}^{m} Q_i(\ell). \tag{11}$$

Recall that we assumed that for $u \geq 20$ and all $i = 1,2,\ldots,12$, $q_i(u) = q$, a constant. Recall also that m is 120 so that $q^{m-19} = q^{99}$ is negligible for *values of q of interest*. From (9) we have

$$\begin{aligned} Q_i(\ell) &= \prod_{u=0}^{\ell} q_i(u), && \ell = 0,1,\ldots,19 \\ &= Q_i(19)\, q^{\ell-19}, && \ell \geq 19. \end{aligned}$$

Using these with (11) and (10) gives for the steady-state stock level

$$S = \sum_{i=1}^{12} \left| \sum_{\ell=0}^{18} Q_i(\ell) + \frac{Q_i(19)}{1-q} \right| g_i \ . \tag{12}$$

To illustrate the use of (12), Table 4 gives the life distributions $Q_i(u)$ for the continuation rates in Table 3 for $\ell \leq 19$. Using the constant recruitment policy shown in Table 5 and q = 0.980, the steady-state stocks will become 163,149.

In addition to calculating S, many more steady-state calculations of interest can be made. For example, the steady-state fraction with less than high school education is given by

$$(\lambda_1 g_1 + \lambda_2 g_2 + \lambda_5 g_5 + \lambda_6 g_6 + \lambda_9 g_9 + \lambda_{10} g_{10})/S. \tag{13}$$

Similarly, the steady-state fraction of non-Caucasians in the force is given by

$$(\lambda_2 g_2 + \lambda_4 g_4 + \lambda_6 g_6 + \lambda_8 g_8 + \lambda_{10} g_{10} + \lambda_{12} g_{12})/S. \tag{14}$$

Table 4

Cumulative Tail Distributions of Length of Service

	Cohort Number											
LOS	1	2	3	4	5	6	7	8	9	10	11	12
0	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
1	0.850	0.850	0.880	0.880	0.850	0.850	0.880	0.880	0.850	0.850	0.880	0.880
2	1.064	1.346	0.878	0.942	0.859	0.933	0.868	0.914	0.846	0.878	0.865	0.890
3	1.008	1.389	0.874	0.927	0.836	0.924	0.847	0.900	0.808	0.864	0.853	0.883
4	0.951	1.312	0.870	0.930	0.779	0.846	0.828	0.859	0.749	0.810	0.835	0.851
5	0.881	1.189	0.864	0.908	0.711	0.756	0.823	0.827	0.693	0.736	0.822	0.848
6	0.839	1.125	0.850	0.880	0.649	0.710	0.811	0.786	0.646	0.653	0.807	0.820
7	0.705	0.916	0.775	0.802	0.608	0.607	0.787	0.757	0.598	0.598	0.792	0.796
8	0.183	0.294	0.274	0.285	0.556	0.526	0.773	0.751	0.545	0.528	0.782	0.779
9	0.103	0.152	0.196	0.174	0.503	0.477	0.744	0.734	0.495	0.486	0.757	0.738
10	0.048	0.099	0.157	0.110	0.468	0.421	0.710	0.703	0.447	0.416	0.739	0.695
11	0.030	0.093	0.123	0.091	0.406	0.362	0.621	0.614	0.402	0.368	0.723	0.664
12	0.020	0.059	0.061	0.060	0.102	0.113	0.157	0.210	0.369	0.322	0.713	0.635
13	0.014	0.038	0.053	0.051	0.053	0.065	0.098	0.144	0.342	0.293	0.692	0.616
14	0.013	0.027	0.045	0.039	0.033	0.045	0.077	0.110	0.320	0.269	0.672	0.579
15	0.010	0.021	0.036	0.031	0.025	0.028	0.065	0.088	0.280	0.234	0.609	0.538
16	0.009	0.015	0.024	0.022	0.019	0.020	0.056	0.064	0.080	0.075	0.172	0.250
17	0.006	0.010	0.021	0.010	0.017	0.018	0.056	0.053	0.049	0.047	0.111	0.185
18	0.004	0.010	0.018	0.009	0.016	0.011	0.056	0.053	0.037	0.036	0.091	0.143
19	0.003	0.008	0.013	0.008	0.015	0.011	0.058	0.039	0.031	0.033	0.083	0.130

Table 5

Quarterly Input of Recruits Into Each Cohort

Cohort Number	Number of Recruits
1	--
2	--
3	--
4	--
5	1428
6	252
7	2142
8	378
9	2652
10	468
11	3978
12	702
TOTAL	12,000

Interactive Program Illustration

In this section, we describe the use of a set of interactive APL functions for both data input and enlisted end strength forecasting. These functions are available in Scientific Time Sharing's APL+ system in a workspace called ENLISTED. Listings and documentation of the functions are given in the Appendix.

The APL program has been implemented in close cooperation with the staff of Manpower Management Information Systems (Code MPI-20) at Marine Corps Headquarters. As indicated previously, the cohort model is currently being used by MPI-20 as a personnel planning and management tool.

Data Input and Storage

The three functions used to input, display, and correct the stocks $\{S_i(t;u)\}$ for any given time period t are as follows:

1. INPUTSTK.
2. DISPLAYSTK.
3. CORRECTSTK.

INPUTSTK is a function that requires no arguments. It asks the user for the time period t, and for each cohort $i = 1,2,\ldots,12$, it asks for 20 numbers $\{S_i(t;u),\ u = 1,2,\ldots,20\}$. After these are entered, it asks for the remainder of the force, c(t). A sample use of INPUTSTK is shown in Figure 2. The data is stored in a file called "4894733 STOCKS"; details of the file format can be found in the Appendix.

DISPLAYSTK is a monadic function that takes, as its right-hand argument, a 2-element vector of month and year, and displays the stocks for that time period with suitable headings. Figure 3 demonstrates the use of DISPLAYSTK for data on 31 March 1976.

CORRECTSTK is a monadic function that takes, as its right-hand argument, a 2-element vector of month and year. After using DISPLAYSTK to observe the stocks on file, CORRECTSTK can be used to make any necessary corrections. A sample use of CORRECTSTK is shown in Figure 4.

```
      INPUTSTK
 TIME PERIOD? EG. 9 75 FOR END OF MONTH 9 OF 1975
□:
      3 76
2 LHS  W
LOS    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
□:
       3    5   48  165  527  543  845  380  197   83   43   23   26   20   30   31   22   14    6    4
2 LHS NW
LOS    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
□:
       0    4   12   29   92  154  235  128   80   39   27   31   13   12   19   20    7    4    5    1
2  HS  W
LOS    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
□:
```

Figure 2. Illustration of INPUTSTK.

DISPLAYSTK 3 76

NO.	*TYPE*	1	2	3	4	5	6	7	8	9	10
1	2 *LHS W*	3	5	48	165	527	543	845	380	197	83
2	2 *LHS NW*		4	12	29	92	154	235	128	80	39
3	2 *HS W*	3	14	221	879	806	804	1926	899	248	140
4	2 *HS NW*	2	2	33	117	137	202	541	387	85	51
5	3 *LHS W*	1706	931	907	495	928	672	736	301	794	547
6	3 *LHS NW*	301	134	132	81	211	210	247	108	200	124
7	3 *HS W*	1424	1256	1683	1041	645	495	936	560	545	436
8	3 *HS NW*	422	299	387	236	147	187	299	196	143	108
9	4 *LHS W*	2419	2635	2441	1749	3143	2372	2180	1107	1981	1487
10	4 *LHS NW*	410	497	462	336	897	793	697	356	583	435
11	4 *HS W*	2982	3418	5563	4276	2563	2013	3841	2685	1433	1179
12	4 *HS NW*	588	797	1166	907	582	503	816	700	340	334

LOS

NO.	*TYPE*	11	12	13	14	15	16	17	18	19	20
1	2 *LHS W*	43	23	26	20	30	31	22	14	6	4
2	2 *LHS NW*	27	31	13	12	19	20	7	4	5	1
3	2 *HS W*	174	50	52	25	74	24	17	7	14	6
4	2 *HS NW*	34	21	22	11	24.	18	9	3	5	4
5	3 *LHS W*	508	414	126	61	52	40	26	19	11	10
6	3 *LHS NW*	122	96	39	18	24	11	6	8		2
7	3 *HS W*	876	460	123	70	123	62	25	14	33	19
8	3 *HS NW*	185	124	50	28	41	28	11	4	10	3
9	4 *LHS W*	1688	1721	1502	1187	1282	932	325	150	119	101
10	4 *LHS NW*	387	400	394	360	354	206	70	17	17	32
11	4 *HS W*	2846	1892	1147	1176	2409	1562	285	136	279	157
12	4 *HS NW*	624	407	350	404	530	281	96	44	61	28

NO. WITH LOS>20:- 48049

TOTAL END STR:- 174823

Figure 3. Illustration of DISPLAYSTK.

```
      CORRECTSTK 3 76
TO END, ENTER COHORT NO. 0.  TO CHANGE >20, USE COHORT NO. 1, LOS 21
 COHORT NO.?
⎕:
      12
LOS?
⎕:
      6
CURRENT:-553
NEW?
⎕:
      503
 COHORT NO.?
⎕:
      1
LOS?
⎕:
      21
CURRENT:-48152
NEW?
⎕:
      48049
 COHORT NO.?
⎕:
      0
```

Figure 4. Illustration of CORRECTSTK.

End Strength Forecasts

The function ENDSTR is used to calculate end strengths for given recruitment policies using equation (3). It requires no arguments, but interactively asks the user for the following data:

1. Number of periods to project (call this n).

2. Base period.

After these, it asks for the following data for recruits for each of the next n periods:

3. Percent Caucasian.

4. Percent 3-year enlistments (it is currently assumed that there are no 2-year enlistments).

5. Percent of high school graduates in Caucasian recruits.

6. Percent of high school graduates in non-Caucasian recruits.

7. Total recruits in each period.

8. First 6-month attrition percent for high school graduates.

9. First 6-month attrition percent for nonhigh school graduates.

The answers to 3 through 9 above are used to spread the recruits in each period over the 12 cohorts. The next input required is:

10. Continuation rate method.

11. Information on whether the user wishes to change the continuation rates. If the answer is yes, the user is asked for (a) high school graduate factor, and (b) nonhigh school graduate factor. These factors are used to multiply all the continuation rates for the given cohort type. This approach is used rather than asking the user for changes in each of the 241 rates.

After answers have been given to questions 1 through 11, the end strengths are calculated using equation (3) and stored on a temporary file. When the calculations are completed, a report is printed showing the recruit policies used and the end strengths obtained. Following this printed report, the user is asked if he wishes to continue. If the answer is yes, the user can then pick a subset or all of the questions 1 through 11 to enter different data and rerun the model. An example run follows (Figure 5).

```
     ENDSTR
1.   NO. PERIODS TO PROJECT?
⎕:
     4
2.   BASE PERIOD? EG 12 75
⎕:
     3 76
3. RECRUIT PERCENT WHITE?
     1       2       3       4
⎕:
     85      83      84      85
4. 3 YR SPLIT?
     1       2       3       4
⎕:
     35      37      33      34
5. W HS GRAD PERCENT?
     1       2       3       4
⎕:
     58      55      62      60
6.   NW HS GRAD PERCENT?
     1       2       3       4
⎕:
     60      60      58      58
7.   TOTAL RECRUITS EACH OF NEXT 4 QUARTERS?
     1       2       3       4
⎕:
     12000 11200  11500 11500
8.HS  6 MONTH PERCENT ATTR?
     1       2       3       4
⎕:
     12      12      10      10
9.   LHS 6 MONTH PERCENT ATTRITION?
     1       2       3       4
⎕:
     20      18      17      15
```

Figure 5. Sample use of ENDSTR.

```
10.   RATE METHOD? 1-3
⎕:
          2
CHANGE RATES? NO


          USMC FORECASTED ENDSTRENGTHS          9 MARCH 1977


BASE PERIOD: 3 76
RATE METHOD: 2
HS FACTOR: 1
LHS FACTOR: 1

     PERIOD    PERC W  PERC 3YR     W-HS     NW-HS     HS-RA    LHS-RA  RECRUITS    END STR TOTAL ATTR
                                                                                    174823
          1        85        35       58        60        12        20     12000    173669      13154
          2        83        37       55        60        12        18     11200    170361      14508
          3        84        33       62        58        10        17     11500    169806      12055
          4        85        34       60        58        10        15     11500    169490      11816
STDY. STATE                                                                         158906
CONTINUE? YES
 QUEST NOS.?
⎕:
          10 7
10.   RATE METHOD? 1-3
⎕:
          1
7.    TOTAL RECRUITS EACH OF NEXT 4 QUARTERS?
          1      2      3      4
⎕:
          4ρ12000
```

Figure 5 (Continued).

CHANGE RATES? YES
HS GRAD FACTOR?
⎕:
1.01
LHS FACTOR?
⎕:
1.02

USMC FORECASTED ENDSTRENGTHS 9 MARCH 1977

BASE PERIOD: 3 76
RATE METHOD: 1
HS FACTOR: 1.01
LHS FACTOR: 1.02

PERIOD	PERC W	PERC 3YR	W-HS	NW-HS	HS-RA	LHS-RA	RECRUITS	END STR	TOTAL ATTR
								174823	
1	85	35	58	60	12	20	12000	175245	11578
2	83	37	55	60	12	18	12000	173892	13353
3	84	33	62	58	10	17	12000	174976	10916
4	85	34	60	58	10	15	12000	176154	10822
STDY. STATE								198347	

CONTINUE? NO_

Figure 5 (Continued).

CONCLUSIONS

Analysis of Marine Corps data allows us to conclude that the historical data are available to obtain continuation rate values for each cohort and LOS type needed in the forecasting equations of the model. The rates of recruit attrition for the first 6 months of enlistment are considered a control variable by the Marine Corps; hence, the interactive program allows the user to enter his own recruit attrition rates directly at the terminal.

Since members of each of the 12 cohorts can remain in the Navy for 30 years (120 quarters), the complete cohort model would require 1452 continuation rates to accommodate all cohort/LOS categories. Since retention behavior is relatively independent of cohort type for marines with an LOS greater than 5 years, all marines in this category were combined into one class. This reduced model size to only 241 continuation rates, a considerable savings in data requirements and computation time.

RECOMMENDATIONS

Based on gaming experience with the model, optimization features should be implemented in order to evaluate strategies for attaining both short- and long-term manpower planning goals, such as minimizing discounted costs or maintaining a stable force under uncertain future manpower requirements. These should include features to measure budgetary effects of various promotion and retention policies.

APPENDIX

DETAILED LISTING OF APL FUNCTIONS

DETAILED LISTING OF APL FUNCTIONS

Files

The forecast model requires two files for execution. The file "4894733 STOCKS" contains historical data on enlisted Marines (for details of file creation, manipulation, and security, see the booklet on the APL+ file subsystem from Scientific Share Corporation). Component 1 of this file contains data for 30 June 1975; component 2, the data for 30 September 1975; etc. The format of the data is shown in Figure 3 of the main report.

The file, "4794733 FORECAST," is used to store the forecasted force whenever the function ENDSTR is used. After completion of the use of ENDSTR, these files are erased. They are used only to facilitate the printing of various statistics on the forecasted force.

Functions

The use of the main functions is discussed in the main report. This appendix contains detailed listings of the functions.

```
   ∇ENDSTR[⎕]∇
 ∇ ENDSTR;BPI;NQ;QI;QN;PT;V;NW;PRMT;Y4;Y3;WG;NWG;HSA;LHSA;CV;RV;HSF;LHSF;T;N
  ⍝TIE FILES AND SET UP
   ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1 ◇ '4894733 FORECAST' ⎕FSTIE 2 ◇ ⎕FDROP 2,-/2↑⎕FSIZE 2
  ⍝SET QUESTION VECTOR
   NQ←ρQI←QN←L9,L1,L2,L3,L4,L10,L5,L6,L11,L7 ◇ PT←0 ◇ →LPT
  ⍝RECRUIT DATA INPUT
  L9:(LIT QN⍳L9),'. ',' NO. PERIODS TO PROJECT?' ◇ NP←⎕ ◇ →LPT
  L1:(LIT QN⍳L1),'.     BASE PERIOD? EG 12 75' ◇ →(2=ρBP←⎕)ρLBP ◇ EM ◇ →L1
  LBP:BPI←¯1+(BP[1]÷3)+4×BP[2]-75 ◇ →LPT
  L2:(LIT QN⍳L2),'. RECRUIT PERCENT WHITE?' ◇ ⍞←PRMT←,'I7' ⎕FMT⍳NP ◇ →(NP≠ρNW←1-W←0.01×,⎕)ρL2E ◇ →LPT
  L2E:EM ◇ →L2
  L3:(LIT QN⍳L3),'. 3 YR SPLIT?' ◇ PRMT ◇ →(NP≠ρY4←1-Y3←0.01×,⎕)ρL3E ◇ →LPT
  L3E:EM ◇ →L3
  L4:(LIT QN⍳L4),'. W HS GRAD PERCENT?' ◇ PRMT ◇ →(NP≠ρWG←0.01×,⎕)ρL4E ◇ →LPT
  L4E:EM ◇ →L4
  L10:(LIT QN⍳L10),'.  NW HS GRAD PERCENT?' ◇ PRMT ◇ →(NP≠ρNWG←0.01×,⎕)ρL10E ◇ →LPT
  L10E:EM ◇ →L10
  L5:(LIT QN⍳L5),'.     TOTAL RECRUITS EACH OF NEXT ',(LIT NP),' QUARTERS?' ◇ PRMT
   →(NP=ρT←,⎕)ρLPT ◇ EM ◇ →L5
   ' RECRUIT ATTRITION'
  L6:(LIT QN⍳L6),'.HS  6 MONTH PERCENT ATTR?' ◇ PRMT ◇ →(NP≠ρHSA←0.01×,⎕)ρL6E ◇ →LPT
  L6E:EM ◇ →L6
  L11:(LIT QN⍳L11),'.  LHS 6 MONTH PERCENT ATTRITION?' ◇ PRMT ◇ →(NP≠ρLHSA←0.01×,⎕)ρL11E ◇ →LPT
  L11E:EM ◇ →L11
  L7:(LIT QN⍳L7),'.     RATE METHOD? 1←';BPI←1 ◇ N←⎕ ◇ →LPT
  ⍝CALCULATE CONT. RATES
  LCALC:RA←(12,NP)ρLHSA,LHSA,HSA,HSA ◇ CR←RATE N ◇ HSF←LHSF←1
   →(~AYN 'CHANGE RATES?')ρLC ◇ 'HS GRAD FACTOR?' ◇ HSF←⎕ ◇ 'LHS FACTOR?' ◇ LHSF←⎕
  CR[RV;CV]←HSF×CR[RV← 3 4 7 8 11 12 ;CV←⍳18] ◇ CR[¯2+RV;CV]←LHSF×CR[¯2+RV;CV]
  ⍝SPREAD RECRUITS
  LC:REC←RECRUITS T
  ⍝AGE FORCE NP PERIODS AND STORE IN FILE FORECAST
   ⎕FDROP 2,-/2↑⎕FSIZE 2 ◇ ((⎕FREAD 1,BPI),[1] 12 21 ρ0) ⎕FAPPEND 2 ◇ AGE NP
  ⍝PRINT OUTPUT REPORT
   PRINTREPORT
   →(AYN 'CONTINUE?')ρLCONT ◇ →0
  LCONT:' QUEST NOS.?'
   NQ←ρQI←,QN[⎕] ◇ PT←1 ◇ →QI[PT]
  LPT:→(NQ<PT←PT+1)ρLCALC ◇ →QI[PT]
 ∇
```

Detailed Listing of APL Functions

```
      ∇AGE[⎕]∇
    ∇ AGE N;I;M;W;A
[1]   ⍝AGES FORCE IN FN 2 AND APPENDS TO FN 2, N TIMES
[2]    I←1
[3]   L1:M←(0 ¯2 ↓M),12↑+/+/ 12 ¯2 ↑M← 12 21 ↑⎕FREAD 2,I ◇ CR←(W,W← 12 1 ⍴(1-RA[;I])*0.5),CR
[4]    (MM,[1] A←M-MM←⌊0.5+CR×M←REC[;I],M) ⎕FAPPEND 2
[5]    →(N≥I←I+1)⍴L1
[6]   ⍝ APPENDS STEADY STATE STOCKS TO FN 2
[7]    CR[;21]←12⍴CR[1;21]÷1-CR[1;21] ◇ ((⍉ 21 12 ⍴REC[;I-1])××\CR) ⎕FAPPEND 2
    ∇
      ∇RECRUITS[⎕]∇
    ∇ M←RECRUITS V
[1]   ⍝ SPREADS RECRUITS OVER COHORTS
[2]    M←(4,NP)⍴0
[3]    M←M,[1](4,NP)⍴(Y3×W×1-WG),(Y3×NW×1-NWG),(Y3×W×WG),Y3×NW×NWG
[4]    M←M,[1](4,NP)⍴(Y4×W×1-WG),(Y4×NW×1-NWG),(Y4×W×WG),Y4×NW×NWG
[5]    M←M×(12,NP)⍴V
    ∇
      ∇RATE[⎕]∇
    ∇ R←RATE N;A;S;CS;CF;I
[1]    I←0 ◇ S← 0 12 21 ⍴0 ◇⍝READ IN STKS
[2]   L1:S←S,[1] A←0=A← 12 21 ↑⎕FREAD 1,BPI-I
[3]    →(N≥I←I+1)⍴L1 ◇ CS← 0 0 19 ↓S ◇ CF←,CS[;1;2]
[4]    R←((12 18 ↑+/[1] ¯1 0 2 ↓S)÷(12 18 ↑+/[1] 1 0 1 ↓S)),12↑(+/¯1↓CF)÷(+/, 1 0 ¯1 ↓CS)++/1↓CF
    ∇
      ∇PRINTREPORT[⎕]∇
    ∇ PRINTREPORT;I;A;M;M1
[1]    2⍴LF ◇ M1←⍉(8,1+NP)⍴(0,⍳NP),(100×(0,W,0,Y3,0,WG,0,NWG,0,HSA,0,LHSA)),0,T
[2]    '          USMC FORECASTED ENDSTRENGTHS              ',DATE ◇ 3⍴LF
[3]    'BASE PERIOD: ';BP ◇ 'RATE METHOD: ';N ◇ 'HS FACTOR: ';HSF ◇ 'LHS FACTOR: ';LHSF ◇ I←0
[4]    LF
[5]    '     PERIOD     PERC W   PERC 3YR      W-HS      NW-HS      HS-RA     LHS-RA   RECRUITS    END STR TOTAL ATTR'
[6]   L1:,'BI10' ⎕FMT M1[1+I;],(+/+/ 12 21 ↑M),+/+/ ¯12 21 ↑M←⎕FREAD 2,I+1
[7]    →(NP≥I←I+1)⍴L1 ◇ 'STDY. STATE',(69⍴' '),,'BI10' ⎕FMT+/+/⎕FREAD 2,I+1
    ∇
```

Detailed Listing of APL Functions

```
      ∇INPUTSTK[⎕]∇
    ∇ INPUTSTK;I;T;CN;M;J;CV;V;X
[1]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[2]   L1:' TIME PERIOD? EG. 9 75 FOR END OF MONTH 9 OF 1975'
[3]    →(2=ρT←,⎕)ρL6 ◇ 'NEED 2 NOS.' ◇ →L1
[4]   L6:→(0=1|X←T[1]÷3)ρL2 ◇ 'MONTH MUST BE 3 6 9 OR 12' ◇ →L1
[5]   L2:CN←¯1+X+4×T[2]-75 ◇ M← 12 20 ρ0 ◇ I←1
[6]   L3:TTLEM[I;] ◇ J←0
[7]   L4:'LOS',,'I5' ⎕FMT⍳20 ◇ →(20=ρV←,⎕)ρL5 ◇ 'NEED 20 NOS.' ◇ →L4
[8]   L5:M[I;]←V
[9]    →(12≥I←I+1)ρL3 ◇ 'REMAINDER OF FORCE'
[10]  L7:→(1=ρY←,⎕)ρL8 ◇ 'ONE NUMBER ONLY' ◇ →L7
[11]  L8:(M←M,12↑Y) ⎕FREPLACE 1,CN
[12]   'TOTAL END STRENGTH:-';+/+/M
    ∇
      ∇DISPLAYSTK[⎕]∇
    ∇ DISPLAYSTK MY;M
[1]   ⍝TO DISPLAY STKS FOR PERIOD MY (MNTH,YR)
[2]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[3]    (50ρ' '),'LOS'
[4]    'NO.   TYPE    ',(,'I5' ⎕FMT⍳20)
[5]    ((12ρ3)⌽'I5' ⎕FMT⍳12),TTLEM,'BI5' ⎕FMT 0 ¯1 ↓M←⎕FREAD 1,¯1+(MY[1]÷3)+4×MY[2]-75
[6]    LF ◇ 'NO. WITH LOS>20:- ';M[1;21] ◇ LF ◇ 'TOTAL END STR:- ';+/+/M
    ∇
      ∇CORRECTSTK[⎕]∇
    ∇ CORRECTSTK MY;CN;I;J;M
[1]   ⍝TO CORRECT DATA IN STOCKS FOR TIME MY
[2]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[3]    M←⎕FREAD 1,CN←¯1+(MY[1]÷3)+4×MY[2]-75
[4]    'TO END, ENTER COHORT NO. 0.  TO CHANGE >20, USE COHORT NO. 1, LOS 21'
[5]   L1:' COHORT NO.?' ◇ →(0=I←⎕)ρL2
[6]    'LOS?' ◇ J←⎕
[7]    'CURRENT:-';M[I;J] ◇ 'NEW?' ◇ M[I;J]←⎕ ◇ →L1
[8]   L2:M ⎕FREPLACE 1,CN
    ∇
```

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